APPENDIX D.

(See rule 61.)

Instructions to Engineer Examiners.

Examiners will require all candidates to fill up a form of which a copy is attached, and they will forward the same to the Collector along with the report of the examination.

For the present the questions for both classes of engineers will be taken from the same book of "Elementary Questions;" and candidates for first class certificates are expected to show their superiority by giving answers more complete than those of the other candidates.

The arithmetical questions for engineers and the *viva voce* examinations for all candidates will be continued as heretofore, and failure in the elementary questions will be treated as failure in arithmetic.

The numbers of the questions for each examination are not to be communicated to the candidate until his examination commences.

New editions with alterations will be issued from time to time.

For the questions to be answered see the Book of Elementary Questions. The questions need not be written, only the answers to them.

Form of Preliminary Questions to be answered by the First Class and Second Class Candidates.

City	Class for which examined.
Date	Candidate's name.

a. Where and how long did you serve in works at the making or at the repairing of engines, and in what capacities?

b. How long have you served as fireman or driver?

c. How long have you served in the engine-room and in what capacities?

d. With what descriptions of engines have you served,—jet condensing, surface condensing, or non-condensing engines, compounds, triples, inverted cylinders, or horizontal engines? What size were the engines?

e. With what descriptions of boilers have you served,—Lancashire, marine, multitubular, sectional or locotype boilers?

f. What engine defects have come under your notice, what caused these defects, and how were they remedied? Give the names of the factory for verification.

g. What boiler defects have come under your notice, what caused these defects, and how were they remedied? Give the names of the factory for verification.

PART III.

82. The Rules in this Part may be called the Bombay Rules for determining the duties of Inspectors, 1903.

INSPECTION OF MATERIAL AND WORKMANSHIP MEASUREMENTS PRIOR TO CALCULATION, &C.

83. Inspectors are required by the Act (see sections 7, 8 and 10) to register boilers, fix the pressure at which they are to be allowed to work, and to grant certificates therefor. (See also rules 94 and 108. See also sections 6 (2) (*c*), 9, 11 and 15 of the Act.)

84. (1) The Inspector shall fix the working pressure for a boiler by making a series of calculations of the strength of the various parts, the calculations being based on his measurements and taking due account, after careful examination, of the material and workmanship, and the details of construction, of each part.

The strength of the weakest part determines the permissible working pressure of the boiler.

In his examination the Inspector may, *if necessary* bore the plates to ascertain their thickness, &c., where the extraction of a rivet or other means will not give the information required.

In all boilers in which the Inspector finds that cast-iron is employed in such a manner as to be subject to the pressure of steam or water, he shall report the circumstances to the Senior Inspector, and shall act in accordance with such instructions as he may receive from him: Provided that the Senior Inspector may by departmental orders authorise Inspectors to omit such reports and exercise their own discretion with regard to fittings of boilers [a] except in the case mentioned in rule 100 A. [a].

(2) In making his calculations the Inspector is to be guided by the formulæ, factors, and constants (corresponding to the ascertained details of the boiler examined) given in the rules for the time being in force (see rule 109).

If no formula, factor, or constant given in the rules is found to correspond to the ascertained details of the boiler examined, the Inspector shall report the matter to the Senior Inspector for his orders.

(3) To ensure the reliability of the results of his examination and calculations the Inspector shall, before granting his certificate, if he considers it necessary or if it is prescribed by rule 105, also hydraulically test the boiler after it has been erected *in situ* (except in the case of boilers examined under the provisions of section 8, sub-section (5) in accordance with the rules for the time being in force regarding such tests.

[a-a] These words were added by G. N. No. 452, General, dated 26th January 1909, *B. G. G.*, 1909, Pt. I, p. 154.

85. (1) In the case of boilers made or altered in India, the Boiler Inspection Department may receive, for examination, before the commencement of the work, plans and particulars of the designs or alterations proposed, in order to avoid questions as to design and material arising during the examination of the finished boilers or alterations. All such plans and particulars of boilers for use in Bombay or in the Mofussil shall be submitted, for examination, to the Senior Inspector, and he shall furnish the proposers with his opinion as to whether he is satisfied that the design and dimensions are suitable for the proposed pressure, or, if not, as to what modifications may be necessary therein.

(2) When plans and particulars of boilers, or of proposed alterations, have been so received and approved, the Inspector, in making his examination prior to granting a certificate, shall see that the designs, as approved, have been carefully followed out, and that the materials correspond with the approved particulars furnished, and he shall further carefully examine the workmanship, and hydraulically test the boiler in accordance with the rules in force.

(3) When granting the *first* certificate under the Act in the case of any new boiler made in, and imported from, Europe, the Boiler Inspection Department may receive the certificate of well-known and reliable makers that the boiler has been constructed by them, and hydraulically tested, to comply with the provisions of the inspection rules for the time being in force under the Act. Such certificate shall further specify the tests to which the boiler was subjected, the date on which the test was carried out, the results thereof, and the safe working pressure it is designed to bear, and shall also contain details of the nature and dimensions of the materials of which the boiler is made.

(4) Such certificates must be forwarded to the Senior Inspector in original and he shall exercise his discretion as to the acceptance and reliability in whole or in part of the statements contained therein in respect of any such boiler, and may authorise (in writing) the Inspector, who is to grant the certificate under the Act, to relax his inspection of any such boiler regarding those points on which the Senior Inspector deems it safe to accept the maker's certificate: Provided that no hydraulic test specified in such certificate shall be accepted as sufficient, unless the name of the maker and his number for the boiler and the initials of the Inspector who conducted the test are stamped indelibly on the boiler and correspond with similar references in the test certificate (which must bear the signature and seal of the maker in token of his acceptance thereof), and also provided that the Senior Inspector has carefully satisfied himself by personal inspection or by report of his Deputy that the boiler after erection *in situ* is in as sound a condition as when tested in Europe.

(5) Any relaxation authorised by the Senior Inspector under the above sub-rule 4 does not, however, relieve the Inspector who grants the certificate under the Act from a very careful inspection of all work done on the boiler during the course of its erection *in situ*, nor shall such Inspector omit the hydraulic test prior to granting his certificate unless *specifically* authorised to do so by the Senior Inspector under the provisions above detailed, and further in such event should his inspection convince him that a hydraulic test *in situ* has become absolutely necessary, he shall refer the matter back to the Senior Inspector unless the owner volunteers such a test.

(6) A record of all maker's certificates accepted under the provisions of this rule by the Senior Inspector shall be maintained in the Boiler Inspection Department and, when considered necessary by the Senior Inspector to ensure

the genuineness of such certificate, a reference shall be made by that Department to the makers and the result of such reference shall be recorded, for the information and guidance of Inspectors at the next inspection of the boiler.

86. No Inspector shall grant a certificate for a boiler until he has fully satisfied himself as to its fittings, construction, material, and workmanship, and calculated its safe working pressure in accordance with the rules in force, nor until he has hydraulically tested it when considered necessary or prescribed by the rules.

87. Having regard to many cases in which serious defects have been discovered, Inspectors should take care, in order to ensure proper inspection, that boilers, the whole of the outside of which cannot be readily examined, are cleared whenever they consider it *necessary*, of any concealing covering, supports, or fittings. If the owners in any special case have any good reasons for not wishing to clear them when the Inspector requires it, the Inspector should submit the whole case in detail to the Senior Inspector for his consideration and orders. The Inspector must, however, recollect that he is not to certify as efficient any boiler respecting which he cannot thoroughly satisfy himself. Boilers which have been so cleared should, if the Inspector considers it *necessary*, be subjected to the hydraulic test before the brick work is rebuilt.

Inspectors are also cautioned that a number of cases have occurred in which many screwed steel stays in the water spaces of boilers have broken squarely across in line with the water side of the outer plate in the ordinary course of working. It is sometimes difficult to detect such defects, although they may render the boiler in which they occur quite unfit for the pressure which it would otherwise be capable of bearing. Great vigilance is therefore necessary in the examination of such stays, and Inspectors will find the frequent application of the hydraulic test a valuable aid to the discovery of such broken stays. The surface supported by short-screwed stays should be carefully gauged before, during, and after the hydraulic test, as undue deflection will no doubt occur in the vicinity of any stays that may be broken. It is also desirable that the outer ends of all short-screwed stays should have a small hole drilled axially, of sufficient depth to extend into the body of the stay at least half an inch beyond the plate into which the stay is screwed. If this is done, the breaking of a stay in the above manner will result in slight leakage, and give warning to those in charge. Some makers increase the diameter of the ends of such stays where screwed into the plate above that necessary to meet calculated requirements; this practice is a commendable one, and should be encouraged by Inspectors.

88. Inspectors should record in their inspection books the dates on which boilers are inspected, when and to what extent they have been cleared from brick work or other coverings and whether the boilers were set or not when examined, and if not set, where they were examined.

89. Small boilers must be surveyed and fitted in the same way as large boilers, and must have safety-valves, water-gauges and all other fittings complete; and as regards these fittings, must comply with the same regulations as large boilers.

90. On every inspection of a steam boiler the Inspector shall, if the internal construction and size of the boiler will allow of it, go inside it and make a thorough examination of it.

When the internal construction or size of a boiler will not allow of the Inspector getting inside it, he should act in accordance with the provisions for such cases made under rule 105.

If for special reasons, and for special reasons only, the Inspector cannot go inside a boiler, he shall distinctly state on the face of his certificate his reasons for not being able to do so.

Whenever it is only removable stays that prevent getting in, he must order their removal, and he must see them properly replaced before granting his certificate.

If any part of a boiler near the uptake fire-boxes or furnaces is so constructed, that the Inspector cannot examine it, he is not to give a certificate, but shall report the case to the Senior Inspector for his orders.

If the boiler is too hot for the Inspector to examine the inside efficiently, and with safety and convenience, he should decline to examine the boiler, and absolutely refuse to grant a certificate, until he can make an efficient internal examination.

91. A pressure once allowed in a boiler is not, *under any circumstances whatever*, to be increased unless the Inspector has previously obtained the sanction of the Senior Inspector, whose reasons for permitting any increase shall be recorded.

In cases where an Inspector is of opinion that an increased pressure may with safety be allowed, he shall communicate with the Inspector who last inspected the boiler, and if on learning the reasons why the existing pressure was formerly allowed, the Inspector is still of opinion that it may be increased, he should communicate all the facts of the case to the Senior Inspector; but *the pressure shall not in any case be increased* until the sanction of the Senior Inspector to do so *has been obtained*.

Inspection of and Regulations regarding Fittings.

The requisite fittings.

92. (1) Every boiler must be fitted with at least *two safety-valves*, a *glass water-gauge*, a *steam pressure gauge*, at least *two gauge- or test-cocks* or in lieu thereof a second glass water-gauge, a *man-hole* if possible, *a blow-off (or sludge) cock*, a *steam stop-valve*, a *non-return feed valve* on the feed pipe and fitted close to the shell and such *hand-holes* and *mud-holes* as are necessary for effectively cleaning out the boiler. It is also recommended that the boiler should be provided with a *scum-cock* (especially with foul feed-water or feed-water heated by exhaust steam), a *water stop-valve* on the feed pipe, and a fusible plug.

(2) If two or more boilers are connected, each boiler must be fitted complete with all the above fittings as if it were an entirely separate boiler, and a *water stop-valve* to *each* boiler is also then essential, and may be fitted either between the *non-return feed valve* and boiler, or immediately outside this valve, but it is necessary that one or the other of these valves be fitted direct on the boiler flange; a valve combining the offices of these two valves in one casting is allowable.

(3) No boiler, or steam chamber, is to be so constructed, fitted, or arranged that the escape of steam from it through the safety-valves can be

wholly, or partially intercepted by the action of any other valve, or constructive detail.

Safety-valves.

93. The Inspector, in his examination of a boiler and its appurtenances, is particularly to direct his attention to the safety-valves and should at every inspection satisfy himself that they are in good working order, and if he has any doubts as to the pressure on them he should see them tried under steam and satisfy himself that they blow off properly at the pressure assigned to them, such steam test being *insisted* on before granting the *first* certificate under the Act for the boiler and on all occasions when the pressure is altered.

When carrying out such tests, Inspectors are to use pressure gauges supplied by the Boiler Inspection Department similar to those supplied for the same purpose by the Board of Trade in England.

94. The Inspector shall declare the limits of the resistance to steam pressure to which the safety-valves may be regulated.

When the Inspector has determined the amount of pressure, he is to order the valves to be weighted accordingly and the weights or springs to be fixed in such a manner as to preclude the possibility of their shifting or in any way increasing the pressure, and if considered necessary he is to see this order carried out. The Inspector shall certify that the valves have been ordered to be so regulated, stating the pressure and weights, and further that their condition is as required by the rules in force. This declaration shall be entered on his certificate issued under the Act.

The responsibility incurred by an Inspector in issuing a certificate before he is fully satisfied, on these points is very grave, since by the law he is responsible for certifying that the boiler (as shown in his statement) with all its necessary appurtenances is to the best of his judgment in good condition.

Should it at any time come to an Inspector's knowledge that the weights have been shifted, or the loading of the valves otherwise altered, or that the valves or constructive details have been in any way interfered with so as to increase the pressure without the sanction of the Senior Inspector he is at once to report the facts to that officer. The Inspector is to examine the whole of the valves, weights and springs at every inspection and satisfy himself that they are correct and in good order.

95. Inspectors must see that in all *new boilers, and in others whenever alterations can be easily made*, the safety-valves are placed directly on the boiler, and the *neck* (or part between the valve and the boiler flange and which is bolted on to the boiler flange) should be as short as possible.

Inspectors should note that by the above instruction it is not intended that old boilers which have been previously passed without such an arrangement, should be thrown out of work for alterations to be carried out. In any such case, however, in which an Inspector is of opinion that it is positively dangerous to continue to have a length of pipe between a boiler and its safety-valve, it is his duty at once to insist on the requisite alterations being made before granting a further certificate under the Act.

96. The combined area* per square foot of fire grate surface of the safety-valves should be not less than that given in the following table

* *Note.*—This area should be that on which the steam pressure in the boiler can exert an active opening pressure when the valves are closed. A similar definition of valve area is to be allowed when calculating the permissible loading of any particular valve.

opposite the sanctioned boiler pressure; *provided that the valves shall be* not less than two inches in diameter. This applies to new boilers and to boilers which have not previously received a certificate under the Act. In ascertaining the fire grate area the average length of the grate should be taken [measured from the inner edge of the dead plate to the front of the bridge] and the average width [from side to side of the furnace on the top of the bars].

In the case of small boilers, if it is wished to fit valves of less than two inches diameter, the case should be submitted for the consideration and orders of the Senior Inspector.

If there is only one safety-valve on a boiler, the Inspector should not grant a certificate.

SAFETY-VALVE AREAS.

Boiler Pressure.	Area of Valves per square foot of Fire grate	Boiler Pressure.	Area of Valves per square foot of Fire grate.	Boiler Pressure.	Area of Valves per square foot of Fire grate.	Boiler Pressure.	Area of Valves per square foot of Fire grate.	Boiler Pressure.	Area of Valves per square foot of Fire grate.
Lbs.	Sq. inch.	Lbs.	Sq. inch.	Lbs.	Sq. inch.	Lbs.	Sq. inch.	Lbs.	Sq. inch.
15	1·250	53	·551	90	·357	127	·264	164	·209
16	1·209	54	·543	91	·353	128	·262	165	·208
17	1·171	55	·535	92	·350	129	·260	166	·207
18	1·136	56	·528	93	·347	130	·258	167	·206
19	1·102	57	·520	94	·344	131	·256	168	·204
20	1·071	58	·513	95	·340	132	·255	169	·203
21	1·041	59	·506	96	·337	133	·253	170	·202
22	1·013	60	·500	97	·334	134	·251	171	·201
23	·986	61	·493	98	·331	135	·250	172	·200
24	·961	62	·487	99	·328	136	·248	173	·199
25	·937	63	·480	100	·326	137	·246	174	·198
26	·914	64	·474	101	·323	138	·245	175	·197
27	·892	65	·468	102	·320	139	·243	176	·196
28	·872	66	·462	103	·317	140	·241	177	·195
29	·852	67	·457	104	·315	141	·240	178	·194
30	·833	68	·451	105	·312	142	·238	179	·193
31	·815	69	·446	106	·309	143	·237	180	·192
32	·797	70	·441	107	·307	144	·235	181	·191
33	·781	71	·436	108	·304	145	·234	182	·190
34	·765	72	·431	109	·302	146	232	183	·189
35	·750	73	·426	110	·300	147	·231	184	·188
36	·735	74	·421	111	·297	148	·230	185	·187
37	·721	75	·416	112	·295	149	·228	186	·186
38	·707	76	·412	113	·292	150	·227	187	·185
39	·694	77	·407	114	·290	151	·225	188	·184
40	·681	78	·403	115	·288	152	·224	189	·183
41	·669	79	·398	116	·286	153	·223	190	·182
42	·657	80	·394	117	·284	154	·221	191	·181
43	·646	81	·390	118	·281	155	·220	192	·181
44	·635	82	·386	119	·279	156	·219	193	·180
45	·625	83	·382	120	·277	157	·218	194	·179
46	·614	84	·378	121	·275	158	·216	195	·178
47	·604	85	·375	122	·273	159	·215	196	·177
48	·595	86	·371	123	·271	160	·214	197	·176
49	·585	87	·367	124	·269	161	·213	198	·176
50	·576	88	·364	125	·267	162	·211	199	·175
51	·568	89	·360	126	·265	163	·210	200	·174
52	·59								

97. Care should be taken that each safety-valve has a lift equal to at least one-fourth its diameter; and that the openings for the passage of steam [to and from the valves], as also the waste steam pipe, should each have an effective area of discharge not less than the area or combined area of the valve or *valves* they serve; and where there is a length of waste steam pipe above a valve-box sufficient to enable an appreciable pressure to be exerted on the top of the valve by condensed steam, rain-water, or other cause, a drain pipe must be fitted at the bottom of the waste steam pipe.

In the case of lever valves, if the lever is not bushed with brass, the pins must be of brass; *iron and iron working together must not be passed.*

Too much care cannot be devoted to seeing that there is proper lift, and free means of escape of waste steam, as it is obvious that unless the lift and means for escape of waste steam are ample the effect is the same as reducing the area of the valve or putting on an extra load.

It is recommended when practicable that the valve seats should be secured by studs and nuts.

Glass Water-gauge and gauge-cocks.

98. Inspectors shall see that the bottom fitting of the glass water-gauge, and the lowest gauge-cock, are fixed at a safe level.

At every inspection the Inspector shall see that these fittings are in working order.

Man-holes, other openings, flat surfaces, uptakes, etc.

99. All man-holes, and openings of 20 square inches area or over must be stiffened with compensating rings of at least the same effective sectional area as the plates cut out, and in no case should the plate rings be less in thickness than the plates to which they are attached. Openings in the shells of cylindrical boilers when oval should have their shorter axis placed longitudinally. It is very desirable that the compensating rings round openings in flat surfaces be made of ⌊ or ⌈ iron.

Cast-iron doors are not to be passed.

The neutral part of boiler shells under steam domes must be efficiently stiffened and stayed, as serious accidents have arisen from the want of such precautions.

The flat ends, &c. (especially when they are of steel) of all boilers, as far as the steam space extends, should be fitted with shield, or baffle, plates where exposed to the hot gases in the uptake.

Blow-off (or sludge) cock, hand-holes and mud-holes.

100. At every inspection Inspectors should see that *these fittings are in order.*

[a] 100A. In the case of boilers working at a pressure exceeding 160 lbs. per square inch in respect of which a certificate has not been granted before the 1st day of February 1910, the connecting pipe (if any) between the shell of the boiler and the blow-off cock shall not be made of cast-iron. [a]

[a—a] This rule was inserted by Government Notification No. 452, General, dated 20th January 1909, *B. G. G.*, 1909, Pt. I, p. 154.

Steam and water stop-valves and steam-pipes.

101. A steam stop-valve must always be fitted between the boiler and the steam-pipe; and, where two or more boilers are connected with a steam-receiver or superheater, between each boiler and the steam-receiver or superheater. The object of this is obvious, *viz.*, to avoid the failure of all the boilers through the failure of one.

Similarly where two or more boilers are connected, a water stop-valve must be fitted to *each* boiler to enable its isolation for inspection or repairs.

Inspectors shall also see that the regulations in rule 95, respecting 'necks' of safety-valves, are also observed in connection with the 'necks' of steam stop-valves, which valves should be as close on to the boiler as possible.

Inspectors shall also see at each inspection that the non-return feed valves of boilers are in working order.

In all cases in which a socket expansion joint is fitted to a bent steam-pipe, the Inspector should require a fixed gland and bolts to be fitted, in order to prevent the end of the pipe being forced out of the socket. Fixed glands, and bolts should also be fitted to the expansion joints of straight steam-pipes, as cases have occurred, particularly with small straight pipes, in which the ends of the pipes have been forced out of the sockets.

Inspectors should also pay particular attention to the examination (and testing when they may deem it necessary) of steam-pipes.

The fusible-plug.

102. Inspectors should see that this plug where provided is at that part of the boiler where the heat of the fire produces the greatest effect.

Steam pressure-gauge.

103. Inspectors should frequently examine these at their inspections, to see that their readings are reliable and that safety-valves are not over-weighted to comply with the readings of incorrect pressure-gauges.

See also rule 93 as regards standard gauges to be used in tests.

Economisers and superheaters.

104. Inspectors should see that the safety-valves of economisers and superheaters are in proper working order.

REGULATIONS FOR TESTING BOILERS.

105. All hydraulic tests [except those of boilers examined under the provisions of section 8, sub-section (5)] shall be conducted only after the erection of the boiler *in situ*, but, except as provided for in the second clause of this rule, the setting of a boiler need not be disturbed for the purposes of a hydraulic test unless the Senior Inspector from personal inspection or report of his Deputy considers it essential.

Before granting a certificate Inspectors shall see that all boilers which have not previously had a working certificate under the Act [except such as may be exempted under rule 85, sub-rule (4)], boilers that have been cleared for a thorough repair, and all boilers under examination for a certificate after re-erection [except in the case of boilers examined under the provisions of section 8, sub-section (5)] in a position different to that under which they pre-

viously obtained a certificate, are tested by hydraulic pressure (in accordance with rule 107) previous to the boilers being set and before they are covered in, to test the workmanship, &c.

When the internal construction or size of a boiler will not allow of the Inspector getting inside it, he should see it tested by hydraulic pressure at every certificate inspection at least.

Such boilers should have their lagging removed at the first certificate inspection, unless exempted under rule 85, sub-rule (4). Usually the lagging need not be removed on the second, third and fourth, sixth and seventh and ninth annual inspections, provided no leakage occurs during the hydraulic test, but at all other annual inspections the lagging should be completely removed. This procedure may, however, be departed from at the discretion of the Senior Inspector, to whom each case should be referred before any departure is made.

A hydraulic test should also be made before granting an increased pressure certificate.

In all other cases the Inspector shall exercise his discretion as to the necessity for a hydraulic test before granting a certificate, and he may [under the limitations of rule 85, sub-rule (4)] if he considers it *necessary* also apply the hydraulic test to any boiler at any inspection.

When carrying out hydraulic tests, Inspectors are to use pressure-gauges supplied by the Boiler Inspection Department similar to those supplied for the same purpose by the Board of Trade in England. These tests should always be accompanied by careful sets of gaugings and measurements taken before, during, and after the test to ascertain the amount of bulging, and also the permanent set, if any. The tests should not consist of a mere pumping up of the pressure. See also rule 87.

106. Before testing a boiler the Inspector shall examine it, take the necessary measurements and calculate what *the working pressure* should be (in accordance with the regulations in force), and only test it with reference to *that pressure* in accordance with rule 107. If the test is not satisfactory, the working pressure allowable by calculation must be suitably reduced, unless the owner is willing to make such alterations as will enable the boiler to satisfactorily stand the hydraulic test, when, after alteration, the boiler must be again examined, the pressure being re-calculated (if necessary), and tested to the satisfaction of the Inspector.

The Inspector who determines the pressure must examine the boilers thoroughly during the test, specially with regard to any doubtful detail or place not easy of access during the prior examination, for in the absence of special inspections from the Senior Inspector he will be held responsible for the pressure allowed.

No Inspector, who has not after the application of the hydraulic test been able to examine, or who has not examined, the boiler inside and outside, shall be competent to determine the allowable working pressure of such boiler for the purpose of granting the certificate; but when any Inspector who, after such complete examination as is above prescribed has determined the working pressure, is replaced or succeeded by another Inspector, he may record in writing his decision as to the amount of such pressure allowable, and such decision shall be communicated to the makers, owners or Agents concerned and to his successor, who may then proceed to grant the certificate in respect of such boiler, as if the determination of working pressure had been made by

himself. In the event of the original Inspector having had no opportunity to examine the boiler inside and outside after the hydraulic test, the Inspector granting the certificate must re-test the boiler hydraulically and examine the boiler inside and out before determining the working pressure and granting a certificate.

107. *New boilers* are to be tested by hydraulic pressure according to the following rules :—

(i) Boilers intended to work up to *100 lbs. pressure per square inch, or any pressure below that* are to be tested to *double the working pressure.* Care must be taken, however, that the pressure is not allowed to go above this limit, nor must it be maintained longer than is necessary for a satisfactory test.

(ii) Boilers intended for working pressures *above 100 lbs. per square inch* to be tested to *not less than 100 lbs. above such working pressure.*

In the case of *old boilers*, the Inspector must use his own judgment as to the necessary pressure to be applied, care being taken not to overstrain them, *but the test must always exceed the working pressure.*

108. The amount of the hydraulic pressure, date of test, and the amount to, and the date on, which it was *last* applied to the boiler, should be inserted in the Inspector's certificate (in the 'remarks' column) and recorded in the dimension sheet of the boiler.

FORMULÆ, FACTORS, AND CONSTANTS FOR CALCULATIONS.

General.

109. An Inspector, in making his calculation prior to granting a certificate under the Act, shall be guided in so doing by the following formulæ, factors, and constants appropriate to the several parts [refer also to rule 84, sub-rule *(2)*].

Shell plates and joints.

110. *Factors of safety for shell plates and rivet sections.*

Boilers well designed, well constructed and made of good material should have an advantage in the matter of determining the working pressure over boilers inferior in any of the above respects, as, unless this is done, the superior boiler is placed at a disadvantage, and good workmanship and material will be discouraged. The following rules are, therefore, prescribed :—

When cylindrical boilers are made *of the best material,* with all *rivet holes drilled in place* (see note 1) *and all the seams fitted with double butt straps* and double riveted* (see note 2), *and provided that the boilers have been open to inspection by an Inspector under the Act during the whole period of construction* (see item L in list of addenda following), *then 5 may be used as the factor of safety* in calculations of shell plate strength of *iron boilers* and in calculating strength of *iron rivet sections* and 4·5 in the case of *steel boilers* and *steel rivet sections.*

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* When full allowance is wished for *lap* joints in the longitudinal seams of cylindrical boilers the rivet section, if iron, should be at least $\frac{1}{8}$ times the net plate section, and if steel rivets are used, their section should be at least $\frac{2}{3}\frac{5}{3}$ of the net section of the plate and the tensile strength of the rivet materials not less than 27 tons nor more than 32 tons per square inch. In calculating the safe working pressure, the percentage strength of the rivets may be found in the usual way (by the rules in the appendix), but with iron rivets the percentages so found should be divided by $\frac{1}{8}$ and with steel rivets by $\frac{2}{3}\frac{5}{3}$, the results being the percentages adopted in the calculations.

But when any of the above conditions are not complied with the addenda shown in the following table must be added to the standard factors (5 or 4·5 as the case may be) according to the circumstances of each case in considering the strength of *shell plates*.

Weakening cause.	Addenda.	Instructions.
Rivet holes in longitudinal seams.	A ·15	To be added when all the holes *are fair and good, but drilled out of place after bending.*
	B ·3	Do. do. but drilled out of place *before* bending.
	C ·3	Do. do. but *punched* out of place *after* bending.
	D ·5	Do. do. but *punched* out of place *before* bending.
	E ·75	To be added to any of the above items when all the holes *are not fair and good.*
Rivet holes in circumferential seams.	·1	To be added when all the holes *are fair and good, but drilled out of place after bending.*
	G ·15	Do. do. but drilled out of place *before* bending.
	H ·15	Do. do. but *punched* out of place *after* bending.
	I ·2	Do. do. but *punched* out of place *before* bending.
	J ·2	To be added to any of the four preceding items when all the holes *are not fair and good.*
Rivet holes ...	K ...	When rivet holes of any of the above descriptions have been rimered fair, or bored out fair, *in place*, the case should be submitted to the Senior Inspector as to the reduction or omission of any addenda A to D or F to I, as the case may be, which would otherwise be imposed.
Construction not supervised by Inspector.	L ...	When a boiler has not been open to inspection by an Inspector under the Act during the whole period of construction, the Senior Inspector shall decide (upon such evidence as he can obtain and considers reliable) what is the quality of the workmanship of the rivet holes and by which (if any) of the addenda A to K it is necessary to increase the standard factor of safety. If the Senior Inspector is unable to satisfy himself as regards the workmanship of the rivet holes, 1·65 (=D + E + I + J) shall be the addendum adopted. In this connection refer to rules 3 (*a*) and (*b*).

Weakening cause.	Addenda.	Instructions.
Riveting or joints in longitudinal seams.	M ·2	To be added if the seams are lapped and double riveted instead of the standard double strapped and double riveted.
	N ·1	Do. do. lapped and treble riveted.
	O ·3	Do. do. single butt strapped and double riveted.
	P ·15	Do. do. single butt strapped and treble riveted.
	Q 1·0	Do. when any description of joint is single riveted.
Riveting or joints in circumferential seams.	R ·2	Do. if the seams are lapped and single riveted instead of double strapped and double riveted.
	S ·1	Do. do. lapped and double riveted.
	T ·2	Do. do. single butt strapped and single riveted.
	U ·1	Do. do. single butt strapped and double riveted.
	V ·1	Do. do. double butt strapped and single riveted.
	W ·25	Do. do. lapped, and the strakes of plates are not entirely under and over.
Unusually long boilers (riveting or joints in circumferential seams).		When the length of the boiler exceeds four diameters :
	X ·3	To be added instead of S, U or V if the circumferential seams are fitted as described opposite S, U or V.
	·4	Do. instead of T or R if the circumferential seams are fitted as described opposite T or R.
	Y ...	When, however, such unusually long boilers have their circumferential seams double strapped and double riveted, or lapped and treble riveted, the case shall be submitted to the Senior Inspector for orders.

Weakening cause.	Addenda.	Instructions.
Workmanship and material.	Z ...	When the material or workmanship in any part or joint, or of the rivets, is in any way doubtful, and an Inspector is not satisfied that the addenda given in this table are sufficient to meet the circumstances of the case, he shall report to the Senior Inspector for orders as to any further addendum for faulty material or workmanship and as to an addendum (if any) in calculating strength of rivet sections. Similarly bad details of design, such as if seams are not properly crossed, size and pitch of rivets, &c., should be brought to the notice of the Senior Inspector for his orders. (See note 3.)

Note 1.—Plates that are drilled in place must have been taken apart and the burr taken off and the holes slightly countersunk from the outside.

Note 2.—The shear allowance for double riveting must not be taken more than 75 per cent. greater than for single shear. Butt straps must have been cut from plates and not from bars, and must be of as good a quality as the shell plates, and for the longitudinal seams must be cut across the fibre. In double butt straps each strap must be of at least five-eighths the thickness of the plates they cover. The rivet holes may have been punched or drilled when the plates are punched or drilled out of place, but when drilled in place must have been taken apart and the burr taken off and slightly countersunk from the outside. Single butt straps should be at least one-eighth thicker than the plates they cover.

Note 3.—The diameter of the rivets should in no case be less than the thickness of the plates of which the shell is made, but it will be found when the plates are thin, or when lap joints or single butt straps are adopted, that the diameter of the rivets should be in excess of the thickness of the plates. Formulæ for diameter and pitch of rivets, etc., will be found in the appendix.

Further more it is bad workmanship if punched steel boiler plates of and exceeding $\frac{1}{2}$ inch in thickness are not annealed or the holes rimered, after punching. Steel plates over $\frac{1}{2}$ inch thick should always be drilled. Also all steel plates that have been flanged, or locally heated, and all steel stays and stay tubes which have been locally heated should be carefully annealed after being so treated. Steel plates which have been welded should not be passed if subject to a tensile stress, and these welded, and subject to a compressive stress should be efficiently annealed.

If the conditions enumerated in notes 1, 2 and 3 above are not complied with, the Senior Inspector will exercise his discretion as to an addendum under item Z.

111. *Ultimate tensile or breaking strength of shell plates.*

(a) Iron boilers.

In cases where the Inspector is satisfied, from tests made on the iron from which the boiler shell-plates are made, that it is of a certain ultimate tensile strength per square inch, that strength may be adopted in his calculations; but in no case is a greater tensile strength than 23 tons (say 51,500 lbs.) per square inch with the grain to be adopted. In other cases, provided the Inspector is satisfied that the boiler shell is of good ordinary W. I. boiler-plate, a tensile strength of 21 tons (say 47,000 lbs.) per square inch with the grain

and of 18 tons (say 40,300 lbs.) per square inch across the grain may be adopted.

Before, however, accepting, as the result of tests, the ultimate tensile strength of any iron plates, the Inspector must also satisfy himself as regards the general quality of the iron from tests for elongation, bending, and tempering. The test strips should be 2 inches wide and 10 inches long and when practicable they should be cut from the plate by a planing or shaping machine. The elongation should be not less than 14 per cent. with, or 8 per cent. across, the grain. Bending tests should be done cold.

(b) Steel boilers.

In cases where the Inspector is satisfied, from tests made on the steel from which the boiler shell plates are made, that it is of a certain ultimate tensile strength per square inch, that strength may be adopted in his calculations; but in no case is a greater strength than 32 tons (say 71,700 lbs.) per square inch to be adopted nor should steel of less than 27 tons (say 60,500 lbs.) per square inch tensile strength be allowed in boiler work. In other cases, provided there is sufficient proof that the boiler is of good ordinary steel boiler-plate, a strength of 28 tons (say 62,700 lbs.) may be adopted.

Before, however, accepting, as the result of tests, the ultimate tensile strength of any steel plates, the Inspector must also satisfy himself as regards the general quality of the steel from tests for elongation, bending and tempering. The tests strips should be 2 inches wide and 10 inches long, and when practicable they should be cut from the plate by a planing or shaping machine. The elongation should be about 25 per cent., and not less than 18 per cent., when the strips are tested in the normal condition, but if the plates are annealed by heating in a plate furnace and then cooled on the mill floor, the elongation should not be less than 20 per cent. Bending tests should be done cold.

112. *Ultimate or breaking strength of rivets.*

As with boiler-plates in rule III so with rivets if the Inspector is satisfied from tests made on the material of which the rivets are made that it is of a certain ultimate strength, that strength may be adopted in his calculations. If only tensile tests are available the shearing strength may be taken as four-fifths of the tensile strength. The maximum limits of ultimate shearing strength of rivet material which may be adopted, however, are 22 tons (say 49,300 lbs.) per square inch for *iron rivets*, and 25 tons (say 56,000 lbs.) per square inch for *steel rivets*. Steel rivet material should also be tested for elongation (which should be about 25 per cent. in a length of 10 inches) and for contraction (which should be about 60 per cent.). In other cases, provided the Inspector is satisfied that the rivets are of good ordinary rivet materials, a shearing strength of 21 tons (say 47,000 lbs.) per square inch for *iron rivets*, and of 23 tons (say 51,500 lbs.) per square inch for *steel rivets*, may be adopted.

113. *Formulæ for calculation of shell strength.*

The formulæ will be found in the appendix to these rules.

Flat surfaces, curved ends, stays, and tube plates.

114. *Formulæ for calculations for flat surfaces, curved ends, and stays:*

(i) FLAT SURFACES.

(a) Iron Boilers.

The pressure on plates forming flat surfaces is found by the following formula :

$$\frac{C \times (T + 1)^2}{S-6} = \text{Working pressure, in lbs. per square inch.}$$

T=Thickness of the plate, in sixteenths of an inch.

S=Surface supported by one stay, in square inches.

C=Constant according to the following circumstances :

When the plates are *not* exposed to the impact of heat or flame.

C=100 if the stays are fitted with nuts and washers, the latter being at least three times the diameter of the stays and two-thirds the thickness of the plate they cover.

C=150 if washers are riveted and the diameter at least two-thirds the pitch of the stays, and the thickness not less than the plates they cover.

C=160 if doubling strips are fitted of the same thickness as the plates they cover and not less in width than two-thirds the pitch of the stays.

When doubling plates cover the whole of flat surface, the case should be submitted for the consideration of the Senior Inspector.

C=90 if the stays are fitted with nuts only.

C=67½ if the stays are screwed into the plates and riveted over.

When the plates *are* exposed to the impact of heat or flame, with *steam* in contact with the plates.

C=60 if the stays are fitted with nuts and washers, the latter being at least three times the diameter of the stay and two-thirds the thickness of plates they cover.

C=54 if the stays are fitted with nuts only.

C=36 if the stays are screwed into the plates, and have the ends riveted over to form substantial heads.

When the plates *are* exposed to the impact of heat or flame, with *water* in contact with the plates.

C=80 if the stays are screwed into the plates and fitted with nuts.

C=60 if the stays are screwed into the plates, and have the ends riveted over to form substantial heads.

In cases where plates are stiffened by T or L iron, and a greater pressure is required for the plates than is allowed by the use of the above constants, the case should be submitted for the consideration of the Senior Inspector.

When the riveted ends of screwed stays are much worn or when the nuts are burned, the constants should be reduced, but the Inspector must act according to the circumstances that present themselves at the time of inspection, and it is expected that in cases where the riveted ends of screwed stays in the combustion boxes and furnaces are found in this state, it will be often necessary to reduce the constant 60 to about 36.

When an unstayed circular flat end is bolted or riveted to a cylindrical shell, S in the formula may be taken as the area of the square inscribed in the circle passing through the centres of the bolts or rivets securing the end, provided the angle ring or flange is of sufficient thickness.

In the case of flat surfaces of irregular form where the staying is continuous, and with stays secured by rivets, or with nuts and washers, *as in the end plates of Lancashire and Cornish boilers*, the working pressure may be as follows:

$$\frac{220 \times (T + 1)^2}{d^2 - 12} = \text{Working pressure, in lbs. per square inch.}$$

T = Thickness of end plate, in sixteenths of an inch.

d = Diameter in inches of the largest circle that can be inscribed in the *unstayed area*.

A deduction of 12 per cent. from the allowable pressure should be made for parts exposed to heat and flame.

For flat circular surfaces, such as dome tops, double the above pressure may be allowed.

(*b*) *Steel boilers.*

Provided the quality of the steel complies with the conditions prescribed for furnace plates [see rule 35 (*b*)] for steel boilers the rules for iron boilers may be increased as follows:—

The constants for flat surfaces when they are supported by stays screwed into the plate and *riveted* over so as to form substantial heads, 10 per cent.

The constants for flat surfaces when they are supported by stays screwed into the plate and *nutted*, or when the stays are nutted in the *steam* space, 25 per cent. This is also applicable to the constants for flat surfaces stiffened by riveted washers or doubling strips, and supported by nutted stays.

In the case of flat surfaces of irregular form the working pressure given by the formula above for similar surfaces of iron boilers may be increased 16 per cent., a deduction from this increased pressure of 12 per cent. for exposure to heat and flame being, however, made where necessary as in the case of iron boilers.

(*ii*) CURVED ENDS.

(*a*) *Iron boilers.*

The safe working pressure for dished ends may be found from the following formula:—

$$\frac{4\ T\ hs}{R^2 + h^2} = \text{Working pressure in lbs. per square inch.}$$

T = Thickness of end plate, in inches.

h = Camber of end plate, in inches.

s = Safe stress, in lbs. per square inch of section, for material of end plate.

R = Radius, in inches, of circular (flange) base.

And for a hemispherical end—

$\frac{2\,T\,s}{R}$ = Working pressure, in lbs. per square inch.

s—for hemispherical ends may be taken the same as for iron shell plates (ultimate tensile strength divided by factor of safety suitable to the conditions), but for dished ends should not exceed 5,000 in tension, or 3,000 in compression, and to avoid grooving the flange base should be well rounded at the bend.

(*b*) *Steel boilers.*

s—in the above formula may, for hemispherical ends, be taken the same as for steel shell plates (ultimate tensile strength divided by factors of safety suitable to the conditions), but for dished ends should not exceed 6,500.

(*iii*) STAYS.

(*a*) *Iron work.*

The requisite size of stay bars supporting flat surfaces may be calculated from the following formula :—

$$d = K\sqrt{P\,A.}$$

d = Least *net* diameter of stay, in inches.

P = Working pressure, in lbs. per square inch.

A = Area supported by one stay, in square inches.

K = A variable factor derived from the table given below, where S = safe stress allowed in stay, in lbs. per square inch.

S = ...	4500.	5000.	5500.	6000.	6500.	7000.	7500.	8000.	8500.	9000.
K = ...	·0168	·0160	·0152	·0146	·0140	·0135	·0130	·0126	·0122	·0119

The following are some of the values which may be assigned to S :

S = 5000 on solid screwed stays when they have been welded or worked in the fire.

S = 6000 on the net section of stay tubes, provided that the net thickness is in no case less than ¼ inch.

S = 7000 on solid screwed stays of new boilers which have *not* been welded or worked in the fire.

When the threads of screwed stays are fine the depths of the nuts should be at least 1¼ times the diameter.

The area of *diagonal* stays may be found in the following way: find the area of a direct stay needed to support the surface, multiply this area by the length of the diagonal stay, and divide the product by the length of the perpendicular from the end of the diagonal stay to the surface supported; the quotient will be the area of the diagonal stay required.

The ends of diagonal stays should not be bent, but should be attached with bevelled washers under the nuts, or they may be attached to the shells by a riveted palm.

The area of *gusset* stays should be in excess of that found in the manner indicated above for diagonal stays.

The working tensile stress of *gusset* stays may be found as follows:—

$$\text{Working stress, in lbs. per square inch} = \frac{\text{Area of surface supported, in square inches} \times \text{working pressure, in lbs. per square inch.}}{\text{Depth of web at narrowest part, in inches} \times \text{thickness of web, in inches.}}$$

Note.—Dished ends, unless of the thickness required for a flat end, must be stayed. When dished ends are theoretically equal to the pressure needed, when considered as portions of spheres, the stays when solid may have a stress of 14,000 lbs. per square inch of net section (but the stress should not exceed 10,000 lbs. when the stays have been welded or worked in the fire), and such stays should be properly distributed. If dished ends are not theoretically equal to the pressure needed, they should be stayed as flat surfaces.

(*b*) *Steel Work.*

Provided the tensile strength of the stay bars is from 27 to 32 tons per square inch, with an elongation of about 25 per cent. and not less than 20 per cent. in a length of 10 inches; *solid steel screwed stays which have not been welded or otherwise worked after heating* may be allowed a working stress of 9,000 lbs. per square inch of net section.

For supporting dished ends which are found to be theoretically equal to the pressure needed, *solid steel stays* may, however, have a stress of 18,000 lbs. per square inch of net section.

Provided the tensile strength of strips to form stay tubes is from 26 to 30 tons per square inch, with an elongation of about 25 per cent. but not less than 20 per cent. in a length of 10 inches; *stay tubes of steel* may be allowed a stress not exceeding 7,500 lbs. per square inch of net section so long as their net thickness is in no case less than $\frac{1}{4}$ inch.

Steel stays which have been welded or worked in the fire have been found to be unreliable, therefore they should not be passed (this does not, however, apply to stay tubes which are welded longitudinally).

115. *Formulæ for calculation for tube plates.*

(*a*) *Iron Work.*

The Inspector should not in any case allow a greater compressive stress on the tube plates, due to the pressure on the crown of the fire-box, than 9,000 lbs. per square inch, which is that used in the following formula:—

$$\frac{(D-d)\ T \times 1,800}{W \times D} = \text{Working pressure, in lbs. per square inch.}$$

D = Least horizontal distance between centres of tubes, in inches.

d = Inside diameter of ordinary tubes, in inches.

T = Thickness of tube plate, in inches.

W = Extreme width of combustion box, in inches, from front of tube plate to back of fire-box, or distance between combustion box tube plates when the boiler is double-ended and the box common to the furnaces at both ends.

(*b*) *Steel Work.*

Provided the quality of the steel complies with the conditions prescribed for furnace plates [see rule 35 (*b*)], the compressive stress may be increased to 11,200 lbs. per square inch, *i.e.*, instead of 18,000 use 22,400 in the formula for iron boilers given above.

Girder Supports.

116. *Formulæ for calculations for supporting-girders.*

(*a*) *Iron Work.*

When the tops of combustion boxes, or other parts of a boiler, are supported by solid girders of rectangular section, the following formula should be used for finding the working pressure to be allowed on the girders, assuming that they are not subjected to a greater temperature than the ordinary heat of steam, *and in the case of combustion chambers that the ends are properly fitted to the edges of the tube plate and the back plate of the combustion box.*

$$\frac{C \times d^2 \times T}{(W-P)\ D \times L} = \text{Working pressure, in lbs. per square inch.}$$

W = Inside width of combustion box, in inches, between the sides supporting the girder.

P = Pitch of supporting bolts, in inches.

D = Distance between the girders from centre to centre, in inches.

L = Length of girder, in feet, over all.*

d = Depth of girder, in inches.

T = Thickness of girder, in inches.

N = Number of supporting bolts.

$C = \frac{N \times 1{,}000}{N + 1}$ when the number of bolts is odd.

$C = \frac{(N + 1)\ 1{,}000}{N + 2}$ when the number of bolts is even.

The working pressure for the supporting bolts and for the plate between them should be determined by the rule for ordinary stays and plates.

(*b*) *Steel Work.*

The constants for combustion box supporting girders should be increased 10 per cent., provided that the tensile strength of the steel is from 27 to 32 tons per square inch with an elongation of about 25 per cent. and not less than 20 per cent. in a length of 10 inches.

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* This must in no case be less than W.

If length is equal to outside width of combustion box then 1,000 in the values for the constant C shown above may be increased to 1,050.

Circular Furnaces.

117. *Plain Furnaces.*

(*a*) *Iron Work.*

Circular furnaces with the longitudinal joints welded, or made with a butt strap double riveted, or double butt straps single riveted,

$$\frac{90{,}000 \times \text{the square of the thickness of the plate in inches}}{(\text{Length in feet} + 1) \times \text{diameter in inches}} = \text{Working pressure, in lbs. per square inch.}$$

Provided it does not exceed that found by the following limiting formula :

$$\frac{9{,}000 \times \text{thickness in inches}}{\text{diameter in inches}} = \text{Working pressure, in lbs. per square inch.}$$

The second formula limits the crushing stress on the material to 4,500 lbs. per square inch.

The length to be measured between the rings if the furnace is made with rings.

If the longitudinal joints instead of being butted are lap-jointed in the ordinary way and double riveted, then 75,000 is to be used instead of 90,000, excepting only where the lap is bevelled, and so made as to give the flues the form of a *true* circle, when 80,000 may be used.

When the material or the workmanship is not of the best quality, the constants given above must be suitably reduced ; when neither the material nor the workmanship is of the best quality, such constants will require to be further reduced, according to circumstances and the judgment of the Inspector, as in the case of old boilers. One of the conditions of best workmanship is that the joints are double riveted with single butt straps or single riveted with double butt straps, and the holes drilled after the bending is done, and when in place, and the plates afterwards taken apart, the burr on the holes taken off and the holes slightly countersunk from the outside.

The following examples will serve to show the application of the constants for the different cases that may arise :—

Furnaces with butt joints and drilled rivet holes.	90,000	where the	longitudinal	seams are welded.
	90,000	do.	do.	double riveted and fitted with single butt straps.
	80,000	do.	do.	single riveted and fitted with single butt straps.
	90,000	do.	do.	single riveted and fitted with double butt straps.
Furnaces with butt joints and punched rivet holes.	85,000	where the	longitudinal	seams are double riveted and fitted with single butt straps.
	75,000	do.	do.	single riveted and fitted with single butt straps,
	85,000	do.	do.	single riveted and fitted with double butt straps.
Furnaces with lapped joints and drilled rivet holes.	80,000	where the	longitudinal	seams are double riveted and bevelled.
	75,000	do.	do.	double riveted and not bevelled.
	70,000	do.	do.	single riveted and bevelled.
	65,000	do.	do.	single riveted and not bevelled.
Furnaces with lapped joints and punched rivet holes.	75,000	where the	longitudinal	seams are double riveted and bevelled.
	70,000	do.	do.	double riveted and not bevelled.
	65,000	do.	do.	single riveted and bevelled.
	60,000	do	do.	single riveted and not bevelled.

(*b*) *Steel Work.*

The above constants should be increased 10 per cent., provided the tensile strength of the furnace and combustion box plates is from 26 to 30 tons per square inch and that strips 2 inches wide and 10 inches long cut from the plates will (when heated to cherry red, plunged into water at about 80° and kept there till of the same temperature as the water), bend till the sides are parallel at the distance from each other of not more than three times the thickness of the plates.

118. *Upright fire-boxes, and uptakes of vertical boilers.*

In the case of upright fire-boxes, of donkey or similar boilers, the following percentages should be deducted from the constants given above for plain furnaces, applicable to the respective classes of work, *viz* :—

10 per cent. where the diameter of fire-box decreases at least 1 inch per foot of height;

15 per cent. were the diameter does not decrease;

And percentages intermediate to the above for intermediate coneing.

Proper provision should be made for expansion in the boiler, and fire-boxes should be welded longitudinally.

As the uptakes of hay stack and similar type boilers (including ordinary vertical donkey boilers) where they pass from the fire-box through the steam space are especially liable to injury from overheating, unless careful precautions are taken while steam is being raised, their working pressure should be ascertained by the rules given above for plain circular furnaces (iron or steel), but the corresponding constants used in the calculations should be reduced as 47 to 30, and if flaming coal is regularly used in the furnace the reduction should be as 47 to 22·5.

Makers and owners should, however, be persuaded as far as possible to make the strength of the uptakes in excess of that given by the above rules.

Hoops riveted round can be employed to increase the resistance of the uptake tubes against collapse, but bowling rings (which strengthen while allowing for expansion) are preferable. The use of bowling rings with a moderate thickness of plate is better than very thick plating.

Uptake tubes should preferably be welded, not riveted.

It is also recommended that the uptake should be protected by a cast-iron liner with an air space all round it, or saved from being unduly heated by other efficient means.

The area of uptakes should be about 1/12 to 1/14 of the fire grate area.

119. *Furnaces with anti-collapse rings.*

(*a*) *Iron Work.*

(i) When horizontal furnaces of ordinary diameter are constructed of a series of rings welded longitudinally, and the ends of each ring flanged, and the rings riveted together, and so forming the furnace, the working pressure is found by the following formula, provided the length in inches between the centres of the flanges of the rings is not greater than (120 T—12), and the

flanging is performed at one heat by a suitable flanging machine, *and also the conditions which follow the formula are complied with* :

$$\frac{9{,}000 \times T}{3 \times D}\left(5 - \frac{l + 12}{60 \times T}\right) = \text{Working pressure, in lbs. per square inch.}$$

T = Thickness of plate, in inches.

l = Length between centre of flanges, in inches.

D = Outside diameter of furnace, in inches.

The radii of the flanges on the fire side should be about $1\frac{1}{2}$ inches. The depth of the flanges from the fire side should be three times the diameter of the rivet *plus* $1\frac{1}{2}$ inches, and the thickness of the flanges should be as near the thickness of the body of the plate as practicable. The distance from the edge of the rivet holes to the edge of the flange should not be less than the diameter of the rivet, and the diameter of the rivets at least $\frac{3}{8}$ inch greater than the thickness of the plate. The depth of the ring between the flanges should be not less than three times the diameter of the rivets, the fire edge of the ring should be at about the termination of the curve of flange, and the thickness not less than half the thickness of the furnace plate. Turned rings are such as may be considered a first class method of construction.

The holes in the flanges and rings should be drilled in place if practicable, but if not drilled in place they should be drilled sufficiently small, and afterwards when in place rimered out until the holes are quite fair, the holes should be slightly tapered and the heads of the rivets of moderate size.

After all welding, and after all flanging and heating, each ring should be efficiently annealed in one operation.

(ii) In furnaces of similar construction to the above, when the dimensions as to depth of flanges and size of rivets are less than those there enumerated, then the formula to be used will be :

$$\frac{10{,}000 \times T}{D} = \text{Working pressure, in lbs. per square inch,}$$

provided that the depth of the flanges from the fire side is not less than three times the diameter of the rivet *plus* $1\frac{1}{8}$ inches, and the diameter of the rivet at least $\frac{1}{4}$inch greater than the thickness of the furnace plate.

(*b*) *Steel Work.*

In place of 9,000 and 10,000 above use, the values 9,900 and 11,000, *i.e.*, 10 per cent. in excess of iron strength, provided the quality of the steel complies with the conditions prescribed for furnace plates [see rule 35 (*b*)].

120. *Corrugated furnaces.*

(*a*) *Iron Work.*

The working pressure for corrugated furnaces practically circular and machine-made, provided the plane parts at the ends do not exceed 6 inches in length, and the plates are not less than $\frac{5}{16}$ inch thick should not be greater than found by the following formula :

$$\frac{10{,}000 \times \text{thickness in inches}}{\text{Mean diameter in inches}} = \text{Working pressure, in lbs. per square inch.}$$

(*b*) *Steel Work.*

Provided the quality of the steel complies with the conditions prescribed for furnace plates [see rule 35 (*b*)], when steel furnaces are machine-made by Messrs. The Leeds Forge Company, of the Fox corrugated and Morison suspension types, or by Messrs. John Brown and Company, Sheffield, of the Purves ribbed and grooved type, if they are practically true circles, and the plates not less than $\frac{5}{16}$ inch thick, the working pressure is found by the following formula:

$\frac{C \times T}{D}$ = Working pressure, in lbs. per square inch.

C = 14,000.

T = Thickness, in inches.

D = Outside diameter, in inches, measured at the bottom of the corrugations when the furnace is of the corrugated or suspension type, or over the plain parts when it is of the ribbed and grooved description.

In Fox's corrugated furnaces the pitch of the corrugations and the length of the plain parts at the ends should not exceed 6 inches, and in Morison's suspension furnaces the pitch should not exceed 8 inches, and the length at the ends 5 inches. In both descriptions of furnaces the depth from top of corrugations outside to bottom of corrugations inside should not be less than 2 inches, and the plates at the ends should not be unduly thinned in the flanging.

The plates of ribbed and grooved furnaces should be formed by rolling, the ribs should not be less than 1 $\frac{5}{16}$ inches above the plain parts, and the depth of the grooves not more than $\frac{3}{4}$ inch, the length between the centres of the ribs not over 9 inches and that of the plain parts at the ends not over 6 inches, and the ends rolled slightly thicker than the plain parts, and not reduced at any part by flanging, &c., below the thickness of the body of the furnace.

If the furnace is riveted in two or more lengths the case should be submitted to the Senior Inspector for consideration.

APPENDIX E.

(*See rule 113.*)

Cylindrical Boiler Shells.

Joints with drilled holes.

(*for punched holes, see N.B. at the end*).

Formulæ for ordinary chain riveted and ordinary zigzag riveted joints, and for joints of these descriptions when every alternate rivet in the outer, or in the outer and inner, rows have been omitted (see figures attached).

Let E = Distance from edge of plate or strap, to centre of nearest row of rivets, in inches.

V = Distance between rows of rivets, in inches.